Laser in a test tube

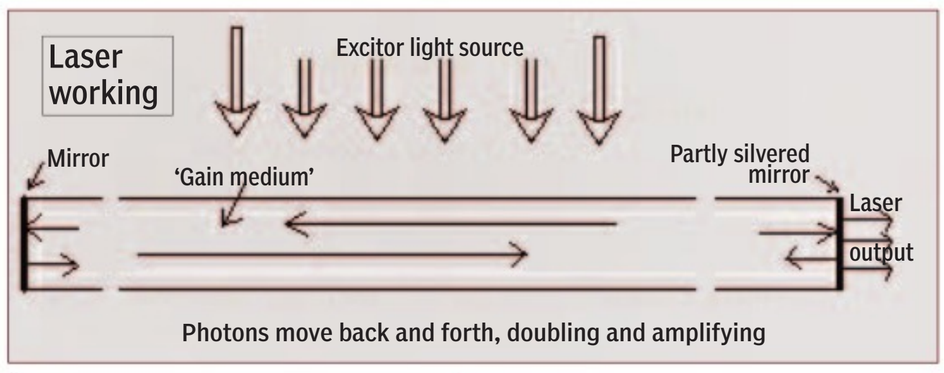
THESE DEVICES CAN NOW BE ACHIEVED BY MIXING CHEMICALS IN THE LABORATORY, WRITES **S ANANTHANARAYANAN**

Metals and semiconductor materials react to light by throwing out electric charges that can be made to run as currents. Or if the free charges fall back, they can give off light energy. These properties are used in electronics, solar cells, lighting devices and lasers, with a very wide area of application. But the devices typically call for precision fabrication at nanometer scales and cannot easily be mass produced. Now a group of scientists at the departments of chemistry, Columbia University and the University of Wisconsin, reports in the journal *Nature Chemistry* that they have got a substance that is of interest in the manufacture of solar cells simply to deposit out of solution in the form of crystals that are just right to work as lasers.

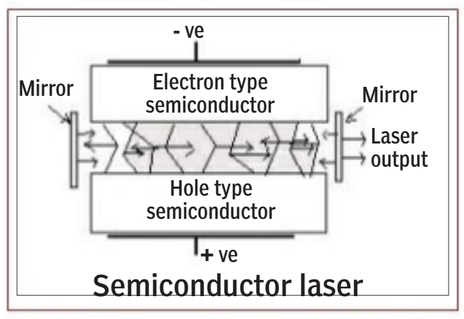
The laser is an arrangement where atoms in some materials get excited to higher energy states and pause a bit before they de-excite and give off a photon of light. But if an atom in the higher state is struck by a passing photon, then the atom de-excites at once, giving off a photon that is just "in step" with the one that stimulated the emission and the two photons are now the amplified laser light. For lasers to work continuously, a good number of the atoms are kept excited and part of the emitted light is fed back to the material by reflectors that are tuned to synchronise. The key requirements are thus the atomic structure that allows the longer-lived excited state and the fabrication of the material to have a pair of exactly placed reflecting surfaces at either end.

The material of lasers can be gases or solid crystals. One form of laser, called the semiconductor laser, gives off light not by the de-exciting of an atom but by free electrons losing energy when they are absorbed by atoms. Now, metals are good conductors of electricity because their atoms have just one or two electrons in the outermost and weakly bound electron shell. These loosely bound electrons can thus move and help carry electricity. But atoms of semiconductors have outer shell electrons that are halfway between being loosely bound and tightly bound. They are, hence, not good as conductors. But if a trace impurity of an atom that has one more or one less outer electron is introduced into a lattice of semiconductor atoms, the impurity is accommodated, but with one electron either "free" or "wanting". This free electron, or the lack of one, which is called a "hole", can then become a carrier of electricity.

Exciting some semiconductors with light also results in electrons building up and if there is a junction of semiconductors that has been oppositely "doped", the electrons can flow only in one direction. On the one hand, a panel of such junctions can create a stream of electrons that are given off when the panel is exposed to light and this arrangement is the *solar cell*. On the other hand, if a pair of such oppositely doped semiconductors is separated by a region into which electrons and "holes" are pumped when a voltage of the correct sense is applied, then the electrons that have been freed by absorbing energy "fall into the holes" and in many cases give off a flash of light. This is the working of



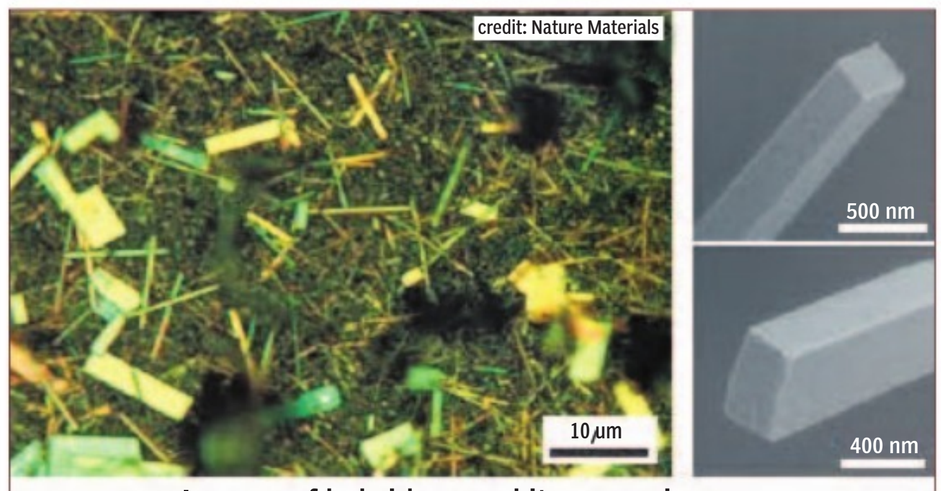
Photons move back and forth, doubling and amplifying



Semiconductor laser

the *Light Emitting Diode*, which is called a diode because it conducts, and lights up, only when it is charged the correct way.

The semiconductor laser works like the Led, with the difference that the electrons and "holes" do not meet to give off a photon at once but float about, at least till a passing photon comes upon them. Then they combine at once and give off a photon, "in step" with the one that pushed them together, just like the excited atom in the normal laser. In the semiconductor laser as well, the light-emitting region is enclosed by reflectors and there is back and forth



Images of hybrid perovskite nanowires

movement of photons and "cascading" to generate a laser beam.

The solar cell application of semiconductors, particularly, now has great relevance in the need for non-polluting energy sources. There is, hence, feverish research going on to create more efficient, more economical and larger solar panels. The current technology is based mostly on processing silicon, which involves many steps, high temperatures and extreme purity. But organic materials with semiconductor properties have now been developed and an important new light harvesting material is a half organic-half inorganic compound that contains lead or tin and atoms like chlorine, which form salts, and which has a crystal structure like a mineral called *perovskite*.

The perovskite structure has many interesting electrical and magnetic properties and endows the organic-inorganic hybrids with merits for use in solar cells. A team at the Universities of Cambridge, Oxford and Munich had discovered that the hybrid converted light to electricity with great efficiency. The material can also be spread on substrates in the form of thin films using a chemical deposition process and this made it doubly attractive for use in solar cells.

Haiming Zhu, Yongping Fu, Fei Meng, Xiaoxi Wu, Zizhou Gong, Qi Ding, Martin V Gustafsson, M Tuan Trinh, Song Jin and X-Y Zhu at Columbia and Wisconsin note that the high efficiency of these materials in solar cells is because of the long time span for which excited states remain and the low rate of recombining without emission of light, the same qualities that are important for working as lasers. The group then developed a simple method to grow organic perovskites into elongated crystals, or *nanowires*, about 10-100 millionths of a metre long by about 400 billionths of a metre (nanometers) across. These elongated crystals, which grow at room temperature and are almost defect-free, form with parallel, plane, reflective ends, just like the laser device needs. The nanowires take about 20 hours to grow once a glass plate coated with a solid reactant. "There's no heat, no vacuum, no special equipment needed," says Song Jin, professor of chemistry at the University of Wisconsin, Madison. "They grow in a beaker on the lab bench."

The paper in *Nature Materials* says the crystals act as lasers with a very low energy threshold, producing laser light of a very high/low frequency spread. And the process of lasing leads to nearly 100 per cent efficiency of energy transfer to emitted light. And with this efficiency of performance, the paper says, there is the ease of production, and then the capacity of easily varying the chemistry of the compounds to tune the frequency of the laser light emitted. "Halide perovskites are ideal for the development of nanophotonics, in parallel with the rapid development in photovoltaics from the same materials," the paper says.

THE WRITER CAN BE CONTACTED AT
simplescience@gmail.com

PLUS POINTS

Spider's eye view

Gil Menda was bored. It was 2012, and his research on facial recognition in wasps was going nowhere. The Cornell University graduate student turned to his advisor, neurophysiologist Ron Hoy. There were jumping spiders in the lab already, so Menda asked for permission to attempt the impossible: to tap into the central nervous system of an arachnid that was far more liable to depressurise and die than sit still for brain surgery. Hoy assented.


Jumping spiders have four pairs of eyes that work in concert to help them sense and capture prey.

The jumping spider is unusual among arachnids, most of which have relatively poor vision compared to insects, even though arachnids have four pairs of eyes. While most spiders build webs and wait for their prey to come to them, the jumping spider stalks and pounces much like a cat, displaying remarkable visual acuity, despite having a brain no larger than a poppy seed.

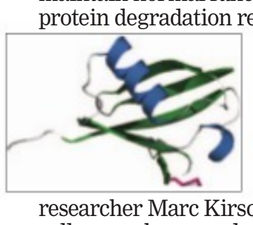
By the time Hoy returned from teaching his class, Menda had succeeded in his efforts. Using an ultrathin metal wire, he'd gently poked a hole in the spider's cuticle that was small enough to self-heal. A glass-insulated tungsten extracellular electrode implanted within range of six neurons in the spider's brain registered data in the form of voltage spikes. Soon, James Golden, a computational neuroscientist, and Eyal Nitzany, a biological statistician, joined the team and they obtained the first recordings from the visual processing centres of male and female jumping spiders' tiny brains.

As technology becomes increasingly focused on high performance in small packages, the team's research offers a visual processing solution on a precise nano- and microscale. Hoy says that for scientists studying dyslexia and autism, "to be able to monitor eye movements in miniature would be fantastic".

BRITTANY TAYLOR/THE SCIENTIST

Cellular disposal

Cells dispose of worn-out proteins to maintain normal function. One type of protein degradation relies upon such proteins being tagged with peptides called ubiquitins so that the cell can recognise them as trash. Harvard researcher Marc Kirschner and his colleagues have used single-molecule fluorescence methods to show how an enzyme adds ubiquitins to proteins and how those proteins are recognised and recycled in the cell's proteosome. They reported their findings in a pair of *Science* papers published on 10 April.



Aaron Ciechanover, Avram Hershko and Irwin Rose, the researchers who discovered the process in the 1980s, shared the 2004 Nobel Prize in Chemistry for their work on ubiquitin-mediated protein degradation. But the molecular particulars of the process remained murky. Kirschner and his colleagues found that an enzyme called APC/C added ubiquitins to proteins headed for the rubbish heap in an iterative fashion, through processive affinity amplification. They also found that the proteosome singled out ubiquitin-tagged proteins for degradation by recognising distributed arrays of short ubiquitin chains, with the configuration of those chains determining how the protein passed through specific channels in the proteosome.

BOB GRANT/THE SCIENTIST

Dino cannibalism?

The 75-million-year-old skull of a juvenile Daspletosaurus — a smaller cousin of Tyrannosaurus rex — found in an Alberta quarry in 1994 carries tooth marks of fellow tyrannosaurs that were inflicted both before and after the young animal's death, according to a study published on 9 April in *PeerJ*.

Researchers from Queen Mary University of London and Alberta's Royal Tyrrell Museum, where the evidence is housed, examined the 21-inch- skull and found multiple bite

marks that matched the shape of tyrannosaur teeth, which could reach up to four inches in length. One bite even punctured the back of the animal's skull. The dinosaur most likely did not die from these injuries, however, since the bone around the puncture marks showed evidence of healing.

"This animal had something of a hard life even though it wasn't an adult," study co-author David Hone of Queen Mary said. "We think of big fights being things for big old warhorses, but clearly younger ones were getting into scraps as well."

CELLULAR MOVEMENT

TAPAN KUMAR MAITRA EXPLAINS THE PROCESS OF MOTILITY AND CONTRACTILITY

The mechanisms underlying eukaryotic motility have increased considerably over the past decade and we now understand that it is driven at the molecular level by a set of ATP-dependent motor molecules. These molecules move sub-cellular components along cytoskeletal elements, which serve as a kind of track to pull these components into position. Two major eukaryotic motility systems are known; one based on the interaction of dynein or kinesin with microtubules, and the other on the interaction of myosin with actin microfilaments. Kinesins and cytoplasmic dynein are motor molecules that move intracellular structures in opposite directions along MT tracks.

The axoneme present in both cilia and flagella is a highly specialised example of dynein-tubulin interaction. The nine outer doublets of the axoneme are connected laterally to one another and radially to the central pair of single microtubules. Dynein arms project out from one MT doublet to the next and slide one set of microtubules past the next. This sliding is resisted by the radial spokes between the doublets and the central pair of tubules and by the connections between adjacent doublets. As a result, the sliding is converted to a bending motion.

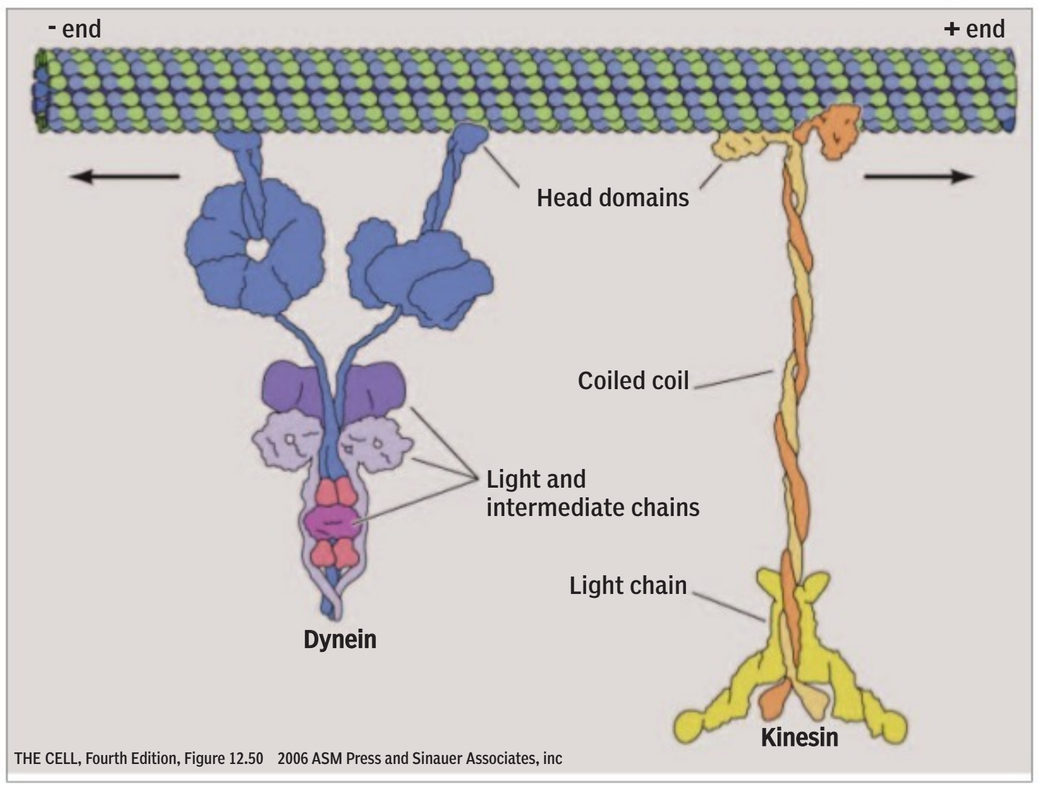
Actin and myosin are widely distributed in non-muscle cells, where they are involved in various sorts of motility, including cell crawling, amoeboid movement, cytoplasmic streaming and cytokinesis. Skeletal muscle contraction is a specialised example of such motility. Muscle contraction involves a progressive sliding of thin actin filaments past thick myosin filaments, driven by the interaction between the ATPase head of the myosin molecules and successive myosin-binding sites on the actin filaments. Contraction is triggered by the release of calcium from the sarcoplasmic reticulum and ceases again as the calcium is actively pumped back into the SR.

In skeletal muscle, calcium binds to troponin and causes a conformational change in tropomyosin, which opens myosin-binding sites on the thin filament. In smooth muscle, the effect of calcium is mediated by calmodulin, which activates myosin light-chain kinase, leading to the phosphorylation of myosin.

The crawling of cells using lamellipodia is a striking example of actin-based motility. In crawling, polymerisation of actin extends cellular protrusions; attachment of the protrusions to the substrate and contraction of the cell drive forward movement.

Other types of actin-dependent movements include amoeboid movement, in which cycles of gelation and solation occur as pseudopodia are extended by amoeboid cells. Movements of particles within cells also depend on actin. These include cyclosis, in plant and algal cells, and cytoplasmic streaming.

THE WRITER IS ASSOCIATE PROFESSOR, HEAD, DEPARTMENT OF BOTANY, ANANDA MOHAN COLLEGE, KOLKATA, AND ALSO FELLOW, BOTANICAL SOCIETY OF BENGAL, AND CAN BE CONTACTED AT
tapanmaitra59@yahoo.co.in

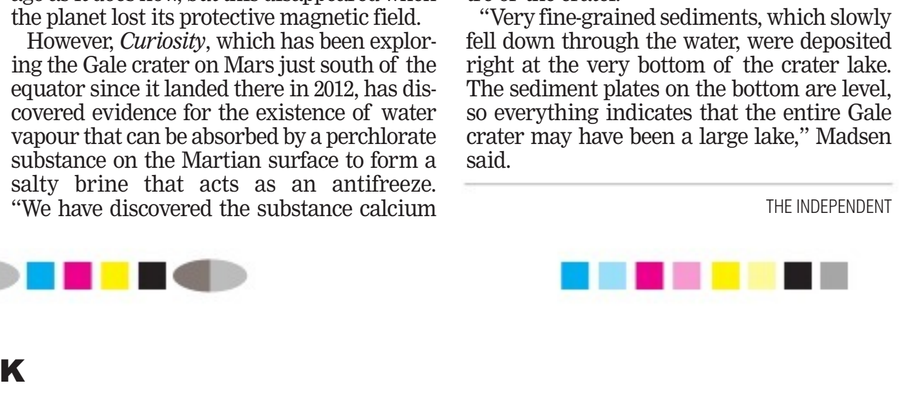


THE CELL, Fourth Edition, Figure 12.50 2006 ASM Press and Sinauer Associates, inc

Need for precaution

NASA'S ROVER DISCOVERS BRINE SUBSTANCE IN MARTIAN SOIL THAT COULD EAT INTO ANY PERMANENT STRUCTURES BUILT FOR FUTURE MANNED MISSIONS, SAYS **STEVE CONNOR**

A new twist on the idea that there could be water on Mars has emerged from data collected by the National Aeronautics and Space Administration's *Curiosity* rover indicating that liquid brine may be ubiquitous across the surface of the Red Planet. Scientists have detected the presence of a chemical substance in the Martian soil that absorbs water vapour from the atmosphere to form a brine that keeps being a liquid even when temperatures on the planet fall below the freezing point of water.


The study suggested that there was once a large lake filling the Gale crater in which the *Curiosity* rover is exploring.

Although liquid water is deemed essential for life, the researchers said the discovery had no immediate implications for the possible existence of microbial life forms on Mars as cosmic radiation bombarding its surface would make be it too hazardous for living organisms to survive. However, they said future space missions to Mars would have to consider taking precautions against any salt-water in the Martian soil as the brine could be "very corrosive" and could eat into any permanent structures built on the surface for future manned missions.

There is now overwhelming evidence that rivers and lakes once existed on Mars many hundreds of millions of years in the past, but that most of this water was lost into space, leaving behind a dry, cold and barren planet. Scientists estimate that Mars had about seven times as much water 4.5 billion years ago as it does now, but this disappeared when the planet lost its protective magnetic field.

However, *Curiosity*, which has been exploring the Gale crater on Mars just south of the equator since it landed there in 2012, has discovered evidence for the existence of water vapour that can be absorbed by a perchlorate substance on the Martian surface to form a salty brine that acts as an antifreeze. "We have discovered the substance calcium perchlorate in the soil and, under the right conditions it absorbs water vapour from the atmosphere," said Morten Madsen of the Niels Bohr Institute at the University of Copenhagen, who was part of the research team that analysed the *Curiosity* data. "Our measurements from the Curiosity rover's weather monitoring station show that these conditions exist at night and just after sunrise in the winter. Based on measurements of humidity and temperature at a height of 1.6 metres and at the surface of the planet, we can estimate the amount of water that is absorbed.

"When night falls, some of the water vapour in the atmosphere condenses on the planet surface as frost, but calcium perchlorate is very absorbent and it forms a brine with the water, so the freezing point is lowered and the frost can turn into a liquid. The soil is porous, so what we are seeing is that the water seeps down through the soil. Over time, other salts may also dissolve in the soil and now that they are liquid, they can move and precipitate elsewhere under the surface," he said.

The study, published in the journal *Nature Geoscience*, suggests that in the past there was a large standing lake filling the Gale crater, which would account for the layers of sediments detected by *Curiosity* on its journey to Mount Sharp, the mountain at the centre of the crater.

"Very fine-grained sediments, which slowly fell down through the water, were deposited right at the very bottom of the crater lake. The sediment plates on the bottom are level, so everything indicates that the entire Gale crater may have been a large lake," Madsen said.

THE INDEPENDENT